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RADIOMETRIC, SPECTRAL AND EFFECTIVENESS EQUIPMENT

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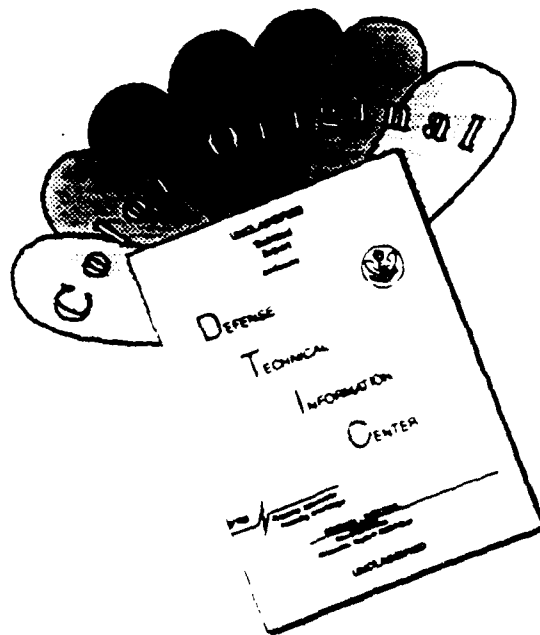
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**This is a description of an assortment of Infrared Radiometric, Spectral and Effectiveness Equipment used for measurement of the radiative output and effectiveness of assorted devices. These instruments are installed and routinely operated at this center and on field flight test. The contents describe some of the instrument parameters and measurement capability.**

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## MINIRAD MODEL SA-100 AND SA-1000 INFRARED BANDED RADIOMETERS

The infrared banded radiometers are used for field measurements of emissive sources. The SA-100 system consists of an optical head and controller. The SA-1000 system has the optical head, the controller and a dedicated data acquisition/data analysis system. The optical heads contain a liquid nitrogen cooled InSb detector and are useful in the 1.1 - 5.5 micrometer wavelength. Both systems are equipped with refractive collecting optics and are used at ranges from 0.1 - 5 km. The field of view of the SA-100 instrument is 3.8 degrees at the 80 percent power points. The field of view of the SA-1000 is either 4.5 or 20 degrees depending on the choice of fore optics. The detector is chopped at 1000 Hz. A manual filter wheel with up to 10 bandpass filters is used to select the wavelength region of interest.

## CI SYSTEMS MODEL SR-5100 BACKGROUND DISCRIMINATING RADIOMETER

The Background Discriminating Radiometer is used for the measurement of radiant intensity of compensation for background. The system consists of an optical head, an electronic controller and a data acquisition/data analysis system. The device uses a liquid nitrogen cooled InSb detector and operates in the region from 1 - 5 micrometers. The instrument uses reflective fore optics and has a field of view of 1.4 degrees at the 50 percent points. Wavelength selection is done by selecting one of six available regions determined by the appropriate choice of bandpass filters. The system is used at ranges of 0.1 - 5 km. Data are recorded and digitized at 200 - 1000 points/second.

The Background Discriminating Radiometer is designed to provide automatic compensation for changes in the background primarily due to a moving target, e.g., an airplane flying through the air. The compensation is performed by chopping the radiometer input between two different fields of view. These two fields of view are separated horizontally in space. Thus one field of view provides the target signature and the other provides the background. In this way changes in the background can be compensated.

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## **MESA, INC., MODEL 1004 FOUR CHANNEL BANDED RADIOMETER**

The four channel banded radiometer is designed to simultaneously measure the radiant intensity from emissive sources in laboratory or field conditions. The system consists of an optical head and a data acquisition/data analysis system. The detectors in this system are standard pyroelectric detectors, spectrally flat from 0.2 - 20 micrometers, with bandpass filters to select the appropriate wavelength regions of interest. Each detector has a germanium lens for collecting optics. The device behaves essentially as a pyroelectric radiometer. The field of view of the system can be either 4.5 degrees or 10 degrees at the 50 percent points. Measurements are done at a rate of 50/second.

## **AGEMA MODEL 880 THERMAL IMAGER**

The thermal imager is used for the measurement of temperature and/or radiant intensity of remote emissive sources under field conditions at ranges of 0.1 to 1.0 km. The unit is an imaging instrument, it is possible to use it for measurement of extended plume sources. The unit consists of a short-wavelength infrared (SWIR) head (InSb) operating from 2 - 5 micrometers, a long-wavelength infrared (LWIR) head (HgCdTe) operating from 8 - 13 micrometers, a dual burst recording unit and associated video monitors. It is a serial scan instrument, providing an interlaced video image for each of two channels at a rate of 6 frames per second. The data is digitally recorded on two high speed Winchester hard disks and a NTSC format video signal is available for recording on standard VHS tape.

The Model 880 system is a calibrated thermal imager. Radiant intensity can be calculated within a given bandpass if range information is known. Currently, the SWIR head is calibrated in the 2.0 - 2.5 and 3.8 - 4.6 micrometer bands. The instrument does not allow simultaneous measurement in these two bands. The LWIR head is calibrated for the total bandpass of this head. The calibration is valid for emissive sources with temperatures up to 1750 degrees C in the 2.0 - 2.5 micrometer bandpass and up to 2000 degrees C in the 3.8 - 4.6 and 8 - 13 micrometer bandpasses.

## **OPTICAL MULTICHANNEL ANALYZER (OMA)**

The Optical Multichannel Analyzer is a spectroscopic tool used for the measurement of visible and near infrared spectra of remote emissive sources. The instrument consists of an optical head and a controller/data interface. The optical head is a grating spectrograph with a focal plane diode array as the recording device. Depending on the type of focal plane array used and the grating selection the instrument can be used for spectroscopy in the ultraviolet, visible or near-infrared spectral region. The maximum scan rate is 30 spectra/second and the instrument is very useful for collecting spectral time histories.

As currently configured the OMA has no front end optics and was originally designed as a laboratory instrument. It has been used successfully in the field in a limited number of tests in the transient velocity windstream apparatus.

## **NICOLET MODEL 170-RS FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETER**

The Nicolet Model 170-RS Fourier Transform Infrared (FTIR) Spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under laboratory conditions at ranges between 0.01 and 0.10 km. The instrument consists of an interferometer spectrometer head and a dedicated data collection/data analysis system. The Model 170-RS is equipped with a two inch diameter zinc selenide collecting lens and has a 25 mrad field of view.

The Nicolet FTIR uses a conventional design Michelson interferometer. The instrument has a liquid nitrogen cooled HgCdTe detector and a zinc selenide beam splitter and operates from 1.6 - 14 micrometers. It can obtain 6 scans per second at a resolution of  $4\text{cm}^{-1}$ . Resolutions as high as  $0.125\text{ cm}^{-1}$  can be obtained with scan times of 7 seconds per scan. Infrared spectra at this resolution have been obtained for illuminating flares. In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event.

The instrument is ideally suited for higher resolution measurements of research and development type flares in a laboratory type environment to obtain emitter identification and temperature measurements based on rotational fine structure of infrared vibrational bands in diatomic and polyatomic molecules.

## **NICOLET MODEL 5-SXC FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETER**

The FTIR spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under laboratory conditions at ranges between 0.01 and 0.10 km. The instrument consists of an interferometer spectrometer head and a dedicated data collection/data analysis system. The 5-SXC is equipped with a two inch diameter zinc selenide collecting lens and has a 50 mrad field of view. The field of view is expandable to 250 mrad if a convex mirror is substituted for the usual plane collection mirror.

The Nicolet FTIR uses a conventional design Michelson interferometer. The instrument has a liquid nitrogen cooled InSb detector and operates from 1.6 - 5.8 micrometers. A similar liquid nitrogen cooled HgCdTe detector and a zinc selenide beam splitter are available to extend the useful range to 14 micrometers. It can obtain 3 scans per second at a resolution of  $4\text{ cm}^{-1}$ . In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event.

## **BOMEN MODEL MB-200 FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETER**

The FTIR spectrometer is an interferometer spectrometer designed for the measurement of spectral radiant intensity from emissive sources under field conditions at ranges between 0.01 and 2.0 km. The instrument is modular consisting of an interferometer spectrometer head, a dedicated signal processor board and a data collection/data analysis system. The MK-100 is equipped with a gathering telescope with a field of view of 28 mrad.

The FTIR uses a unique "wish-bone" design of a Michelson interferometer. The instrument has a liquid nitrogen cooled InSb detector and operates from 1.6 - 5.8 micrometers. It can obtain 64 scans per second at a resolution of  $16\text{ cm}^{-1}$ . In addition to providing spectral radiant intensity as a function of wavelength over the course of a burn, the instrument software allows the spectrum to be integrated over any spectral band of interest within its wavelength range to provide the same type of radiant intensity versus time plots obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpasses and doing several different bandpasses after each event. The instrument is compact and is designed to be a field portable instrument.



## **CIRCULAR VARIABLE FILTER (CVF) SPECTRORADIOMETER**

The CVF spectroradiometer is a multi-purpose instrument designed for the measurement of spectral radiant intensity of emissive sources under field conditions at ranges of 0.5 - 5.0 km. The instrument is modular, consisting of four major components. It is equipped with a 4" silicon/germanium lens collecting optics, uses a liquid nitrogen cooled InSb detector and has a total field of view of 1.5 degrees (90% response). This instrument is similar to the CVF used in the Weapons Division, Naval Air Warfare Center, Pt Mugu, California ATIMS III Pod

The CVF uses a spinning circular variable filter for wavelength separation. It has a wavelength range of 1.8 - 5.4 micrometers with a spectral resolution of 0.03 micrometers and can scan its complete spectral range at a rate of 15 scans/seconds. In addition to providing spectral radiant intensity as a function of time the software in the CVF allows the spectrum to be integrated over any spectral band of interest within its range to provide the same data as obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpass or doing several bandpasses after the event.

## **CI SYSTEMS SR-5000 (CVF) SPECTRORADIOMETER**

The SR-5000 spectroradiometer is a multi-purpose instrument designed for the measurement of spectral radiant intensity of emissive sources under field conditions at ranges of 0.5 - 5.0 km. The instrument is modular, consisting of four major components. It is equipped with a reflective collecting optics, uses a liquid nitrogen cooled InSb/MCT detector and has a variable field of view of .1 mrad to 100 mrad (90% response).

The SR-5000 uses a spinning circular variable filter for wavelength separation. It has a wavelength range of 1.8 - 5.4 micrometers with a spectral resolution of 0.03 micrometers and can scan its complete spectral range at a rate of 30 scans/seconds. In addition to providing spectral radiant intensity as a function of time the software in the SR-5000 allows the spectrum to be integrated over any spectral band of interest within its range to provide the same data as obtained by conventional banded radiometers but with the added flexibility of adjusting the bandpass or doing several bandpasses after the event.

## **PYROELECTRIC DETECTORS**

Pyroelectric detectors are in use for making radiant intensity measurements of emissive sources in both fields and laboratory testing. The pyroelectric systems consist of a Laser Precision Model kT-3000  $\text{LiTaO}_3$  detector, a preamplifier and chopper. The detectors are spectrally flat in the region from 0.2 - 20 micrometers and are equipped with bandpass filters to select the appropriate band of interest. The systems are typically used at ranges of 10 - 30 meters with no collecting optics. The fields of view of the systems at the 50 percent points is 12 degrees.

The output of the detectors is fed into lock-in amplifier. The output of the amplifier is recorded by any number of methods including direct analog to digital conversion by personal computers or recording on a digital storage oscilloscope.

## **RADIOMETRIC TEST FACILITY (RTF)**

The RTF has been in use for many years for development and lot acceptance testing of a variety of pyrotechnic devices including decoy flares, illuminating flares, tracking flares and colored signals. The RTF consists of a burning chamber, a tunnel and two adjacent rooms for instrumentation. The burning chamber in the RTF is 3 meters x 3 meters x 5 meters. The tunnel in the RTF is 2 meters wide by 60 meters long.

In the RTF the air flow for removal of combustion products is from top to bottom. The direction of the air flow was designed in this way to allow the testing of large aircraft parachute illuminating flares that were burned face down to simulate end use. Burning face down with an upward air flow did not provide an accurate representation of the flare output. The combustion products are exhausted through a bag house equipped with filters to remove any solid particulate before release to the atmosphere.

In the RTF the effect of a decoy flare being ejected from an aircraft is simulated by a windstream blowdown apparatus. This apparatus is a 500 gallon reservoir tank that delivers a high velocity air stream through a converging-diverging nozzle system and four inch delivery tube. The air flow through the nozzle system is controlled by a gate valve assembly. When the test is performed an electrical signal causes solenoid valves to actuate to open the gate valve and initiate the igniter assembly on the flare. The air flow from the simulator is parallel to the floor and perpendicular to detector line of sight. The flare grain longitudinal axis is perpendicular to the air flow and the center of the grain is 53 cm from the end of the apparatus. Because of the nature of the exhaust air removal system in the RTF the air stream simulator and the flare grain are located between the detectors and exhaust air system. The air stream blows the combustion products across the burning chamber to a deflector that steers the combustion products behind the burning flare and into the exhaust air flow.

A variety of instrumentation can be used in the RTF. In addition to measuring the radiometer output using pyroelectric radiometers, photometers can be used to measure the visible output and colorimeters can be used to obtain the dominant wavelength and color purity of devices. It is also possible in this facility to collect spectral information in the wavelength regions from 0.25 micrometers to 14 micrometers using grating spectrographs, a circular variable filter spectrometer and Fourier transform infrared spectrometers. Absolute measurements can be made by calibrating the instrumentation against known NIST standards before and after testing.

## **TRANSIENT VELOCITY WINDSTREAM APPARATUS**

The transient velocity windstream apparatus is a free jet expansion windstream apparatus designed to provide adjustable air velocity versus time profiles to simulate the launch of decoy flares from a moving aircraft. The outdoor apparatus consists of several air compressors, a bank of air storage tanks, a computer controlled valve to control air flow, a nozzle, and a thrust/drag test fixture. The device is capable of producing air flows from 0.1 to 0.9 Mach at either a constant velocity or, under computer control, a variable velocity versus time profile. The variable profiles can be adjusted to simulate the observed velocity versus time behavior experienced by a decoy flare when ejected from an aircraft. Run times from 10 to 90 seconds can be obtained depending on the initial velocity chosen. The thrust/drag test fixture and its accompanying software is capable of measuring the drag on the flare, due to the windstream, and the thrust of the flare's rocket motor provided that the flare is capable of thrust.

In a typical experiment a decoy flare is positioned in front of the nozzle of the apparatus. A programmed velocity versus time blowdown is initiated and the flare is ignited at the appropriate velocity. Radiant intensity and spectral radiant intensity are then measured. Instrumentation used includes pyroelectric radiometers equipped with appropriate bandpass filters to select the wavelength region of interest, InSb radiometers with various filters, the circular variable filter spectrometer, grating spectrographs with focal plane array detectors and Fourier transform infrared spectrometers. Measurement distances of 30 meters, 80 meters and 500 meters are typically used. Because of the nature of the test apparatus it is possible to obtain the angular distribution of radiant intensity from 10 - 300 degrees at several different angles simultaneously. Winstream velocity and drag coefficients, in addition to thrust and drag parameters, provided by the thrust/drag test fixture software is used in computer base modeling to predict flare trajectory profiles.



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## **AUTOMATED INFRARED TEST FACILITY (AIRTf)**

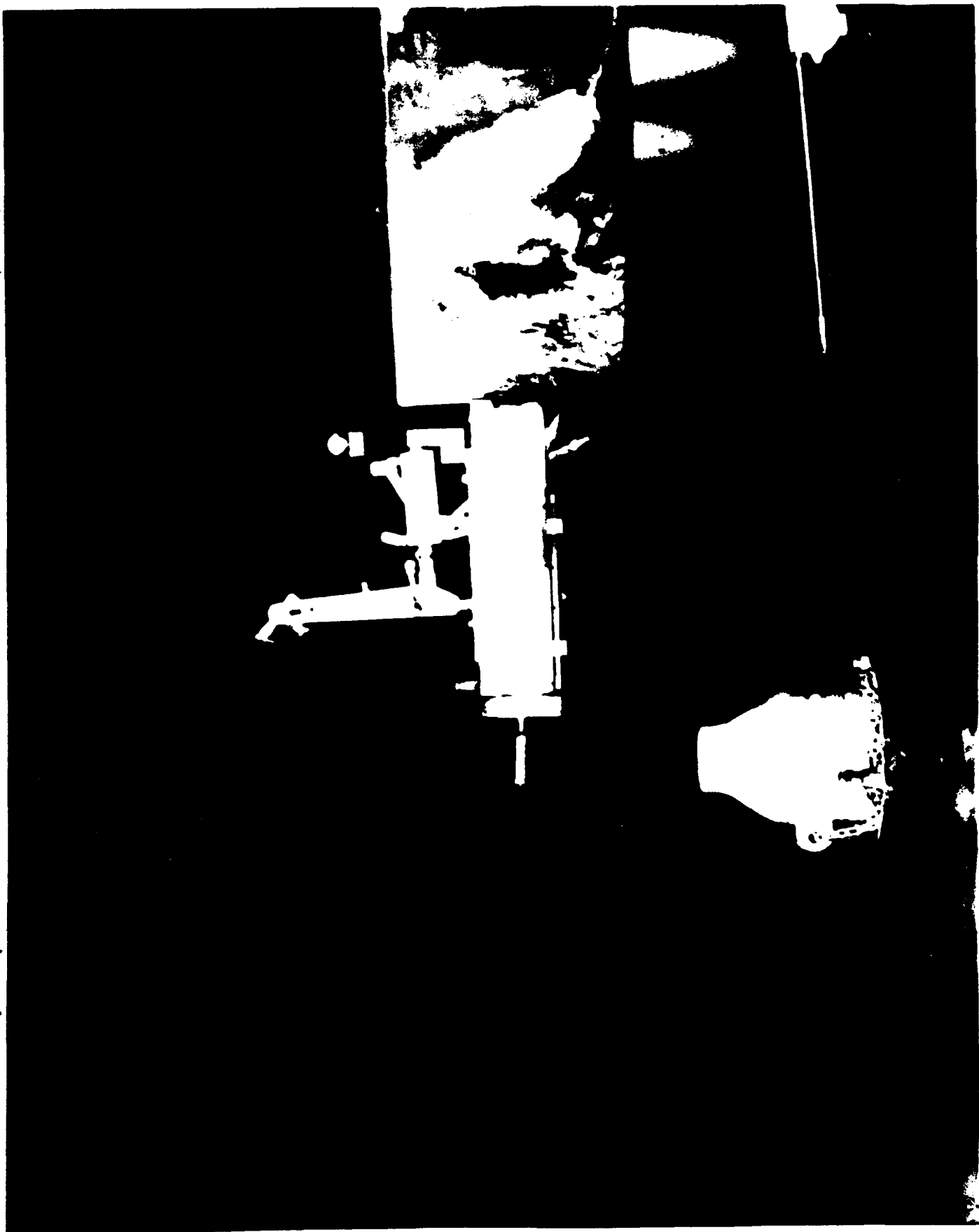
The AIRTf is used for lot acceptance testing of infrared decoy flares. The facility was constructed inside a specially modified inert storage warehouse. The facility consists of a burning chamber, a tunnel and four support rooms adjacent to the tunnel. The burning chamber in the AIRTf is 16 meters long x 8 meters wide x 6 meters high. The tunnel in the AIRTf is 8 meters wide by 50 meters long. A 0.8 meter high baffle is installed on the floor of the tunnel at a distance of 15 meters from the center of the burning chamber to provide a natural baffle on each side.

In the AIRTf air flow for removal of combustion products is from bottom to top. In a static burn the air speed around the flare is controlled by pushing air through the floor and exhausting combustion products from the top. In an air stream test the push air from the bottom is eliminated and replaced with the actual air stream simulator. The combustion products are exhausted through a bag house equipped with filters to remove any solid particulate before release to the atmosphere.

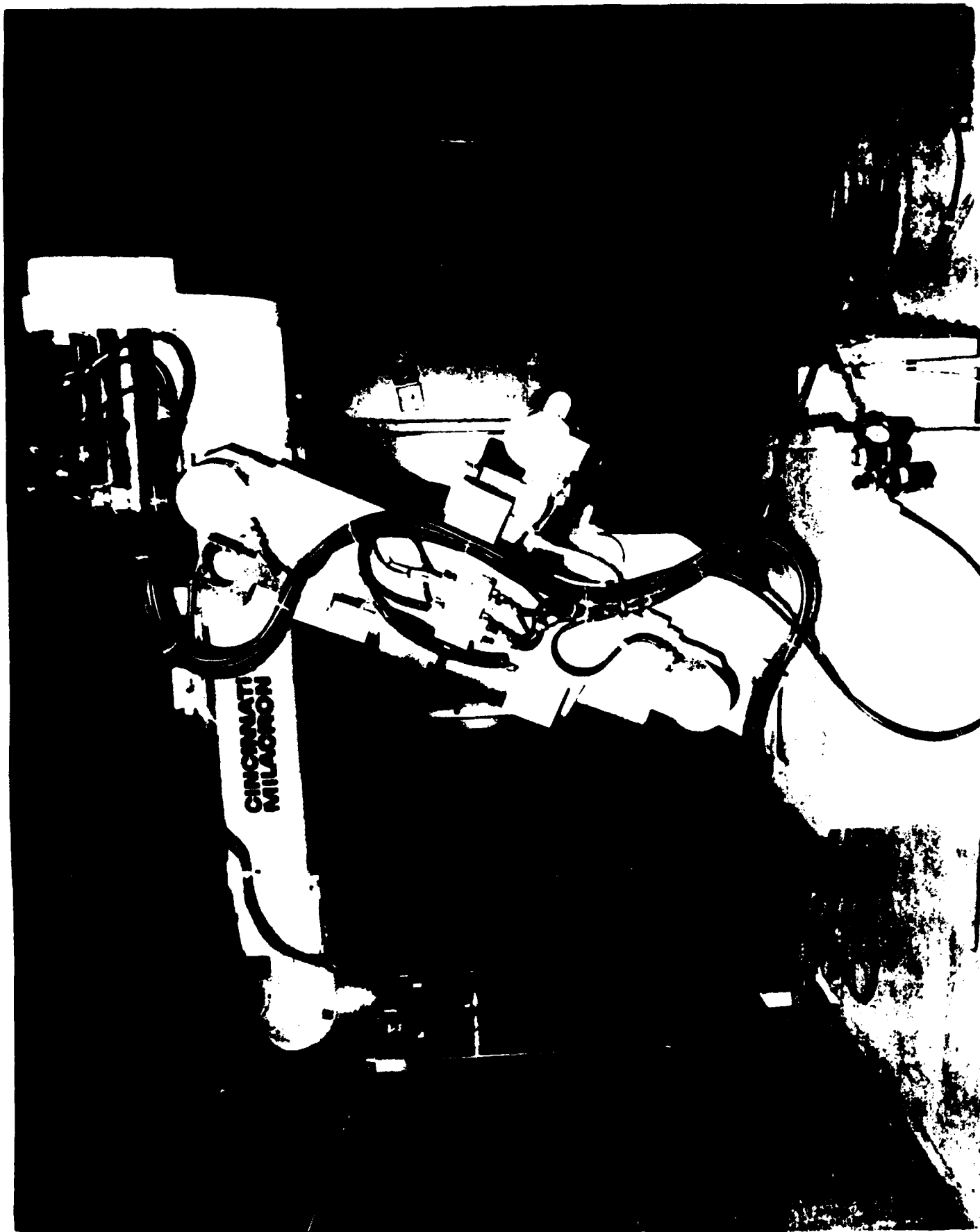
For decoy flare testing an important parameter is the response of the infrared intensity to a high velocity air flow simulating launch of the device from an aircraft. In the AIRTf the air stream simulator is located beneath the floor of the burning chamber with the nozzle protruding through the floor. The air stream is blowing from bottom to top, perpendicular to the floor and the detector line of sight, and directly into the exhaust air system. The flare grain is positioned 53 cm from the end of the nozzle with the longitudinal axis perpendicular to the air flow. Because of the direction of the air flow this makes the longitudinal axis of the grain parallel to the floor. The airstream simulator consists of a 3500 gallon, 100 psi capacity air system with a six inch nozzle which allows various air velocity profiles to be released across the test grain during its burn.

The normal testing sequence is managed by a computerized Automated Test Equipment (ATE) system which also performs the data acquisition and analysis. The data are analyzed in real time and acceptance criteria are imposed as each unit is tested allowing the operator to examine the performance of the test. The test cycle time allows units to be tested at two minute intervals. The ATE allows for calibration of the infrared measurement equipment while in-place in the test tunnel (a true end-to-end calibration). The equipment is housed in an environmentally controlled room which maintains a constant temperature and humidity. This room is semi-mobile to allow the measurement test distance to be changed up to 50 meters.





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## **AUTOMATED VIDEO/IR TRACKING SYSTEM**

The automated video/infrared (IR) tracking system is a mobile system for testing the effectiveness of infrared countermeasures against captive missile seekers in an "endgame" scenario (i.e., the portion of fly-out in which the missile has solved the proportional navigation equation and is on an intercept course). This setup provides an excellent indicator of the overall effectiveness of an infrared countermeasure as a function of range and aspect angle.

The prominent feature of the system is a modified Contraves Kineto Tracking Mount (KTM) Model 443. The KTM is a self-contained trailer and mount. The trailer is a four wheel dual-axle bed with built-in electric distribution system and electric leveling jacks capable of leveling on a 2 deg grade. The mount is a direct drive azimuth/elevation (Az/El) gimbal with two 4x2 feet top and bottom mounting surface. It can track the target at a rate up to 60 deg/sec and accelerate at 60 deg/sec<sup>2</sup>.

The tracker can be operated local (manually) or remote (analog/digital input). The mount is modified and now has a seeker mounting rack capable of holding six or more seekers/cameras in the vertical or look-down mode mounted on top of the KTM. It has a large (30 in. by 16 in.) flat front surface mirror for redirecting the Line of Sight (LOS) of the seekers. The mirror follows the movements of the two arms in such a way that the LOS of the three coincide. A service platform and ladder have also been added. The high pressure gas used for cooling the seekers is a permanently sealed system on the trailer.

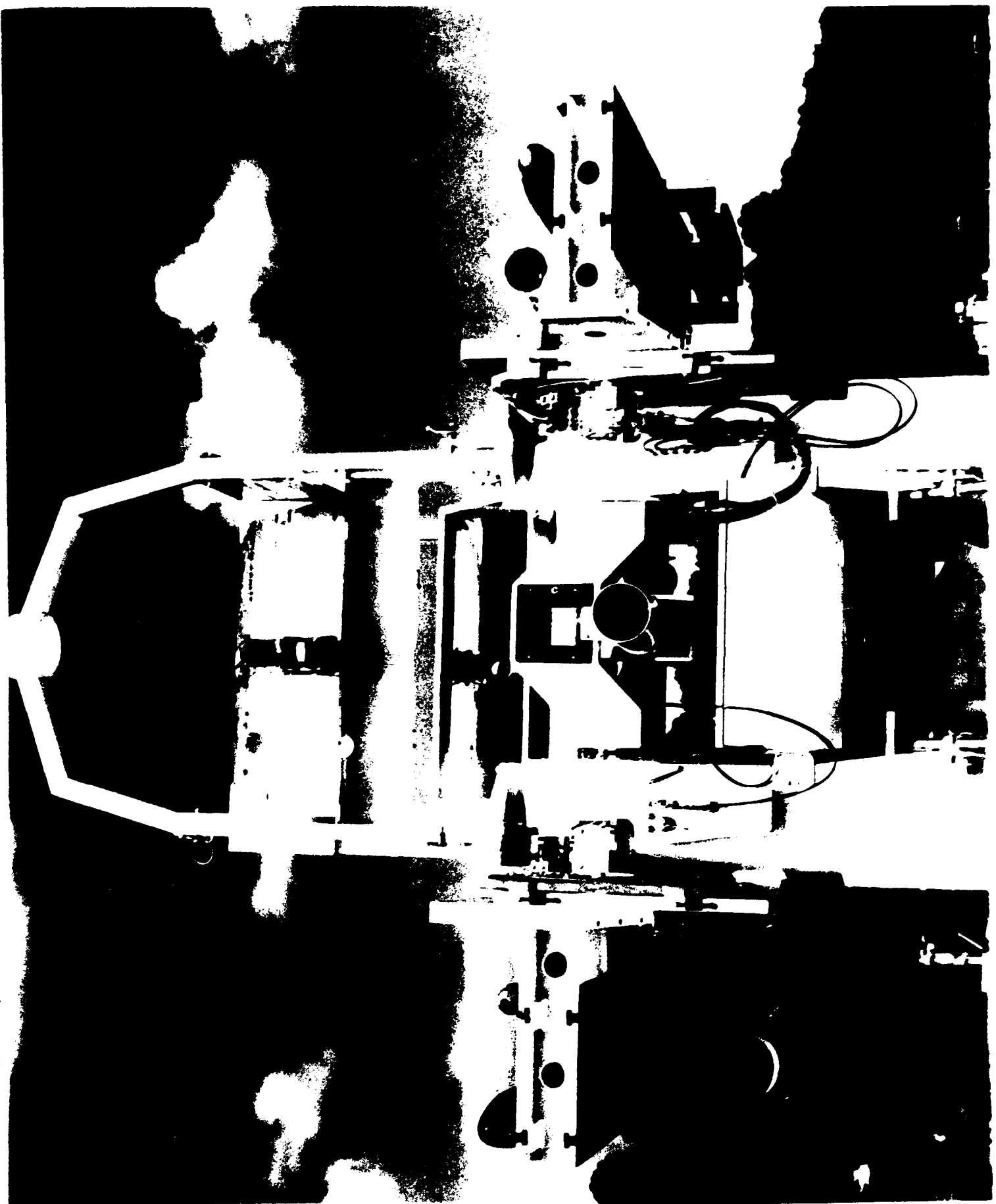
In a test scenario the mount pivots about azimuth axis to track the target horizontally while the mirror tilts to track the target in the vertical direction. Targets with horizontal velocities of up to 60 degrees/second (2600 ft/sec at 2500 feet range) can be tracked with this system. Since the angular forces exerted on the seekers during target tracking are minimized, the end-game scenario is more realistically simulated.

Mount movement can be controlled by using a hand operated joystick, a video image tracker, or an infrared tracker. The PC based remote control unit interfaces with the video, IR and joystick tracking together. It allows for Type I or Type II tracking loops to be used. The PC reads and displays Az and El position and has the capability of sending the information to another device. It has the capability to drive the mount on a preprogrammed path at any point in the tracking.

The built-in autotrack function allows any of the input devices to augment one another in tracking. This makes offset tracking possible and eases the transfer of control from device to device. Video tracking is the preferred mode of tracking for effectiveness testing, it provides the smoothest track while keeping the target centered in the seeker field-of view (FOV).

## **AUTOMATED VIDEO/IR TRACKING SYSTEM**

Seeker signals are monitored and recorded during tests to provide a picture of what the seeker was "thinking" at the time of the countermeasure event. Gyro movement, which indicated whether the seeker is tracking a target or decoy, is superimposed over a video image from the tracking mount. "Instant" results are then obtained by viewing a video monitor and watching the positional indicators. Quick look results and a preliminary indicator of the seeker status are available five minutes following a test flight to assist in planning future flights. Seeker signals and video with positional indicators are recorded on magnetic tape for further in-depth analysis and for use in computer simulations.



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## **THE MEASUREMENT TRACKING SYSTEM**

The measurement tracking system is an automated IR/video mobile system. The main purpose is to collect spectral and radiometric data of IR decoy in real scenarios. The system's primary objective is to track and measure decoy data from dispensing to burnout.

The measurement system also uses the Contraves (KTM) Model 433. The KTM is a self-contained trailer and mount. The trailer is a four wheel dual-axle bed with built-in electric distribution system and electric leveling jacks capable of leveling on a 2 deg grade. The mount is a direct drive azimuth/elevation (Az/El) gimbals with two 4x2 feet top and bottom mounting surface. It can track the target at a rate up to 60 deg/sec and accelerate at 60 deg/sec<sup>2</sup>.

The tracker can also be operated local (manual) or remote (Analog/digital input). The PC based remote control unit interfaces with the video, IR and joystick tracking together. It allows for Type I or Type II tracking loop to be used. The PC reads and displays Az and El position and has the capability of sending the information to another device. It has the capability to drive the mount on a pre-program path at any point in the tracking.

The built-in autotrack function allows any of the input devices to augment one another in tracking. This makes offset tracking possible and eases the transfer of control from device to device. The IR in Type I track mode with computer assisting is the preferred tracking mode. This allows the aircraft to be tracked until dispensing and then the IR decoy is tracked.

A very tight track loop is essential for the small FOV measurement instruments. Typically the instruments used are the CVF, SA-1000, BDR and the 880 Imager but any of the instruments can be mounted on the arms of the tracker depending on space and maintaining balance on the arms. The data, along with video images are sent inside the measurement trailer where the data can be displayed, recorded, printed, and stored.

